Comparing Arctic Sea Ice Kinematics from Satellite Remote Sensing Data to Coupled Sea Ice-Ocean Model Results

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Outline

Comparison of observed RGPS SAR sea ice deformation fields to results from a traditional viscous-plastic sea ice model

- Motivation
- Model and Data
- Comparison
  - Part 1: Dependence on model resolution
  - Part 2: Dependence on model sea ice strength formulation
- Conclusions

Motivation (1)

Sea ice deformation in the Arctic climate system:

- Divergence creates open water ➔ new ice growth in winter
- Convergence creates pressure ridges ➔ thicker ice
- Controls heat and moisture fluxes to the atmosphere and brine rejection to the ocean
- Alters the air and water drag coefficients

➔ Correct modeling of sea ice kinematics important for sea ice mass balance and ocean – air energy fluxes

Motivation (2)

Sea ice model evaluation with ice deformation fields:

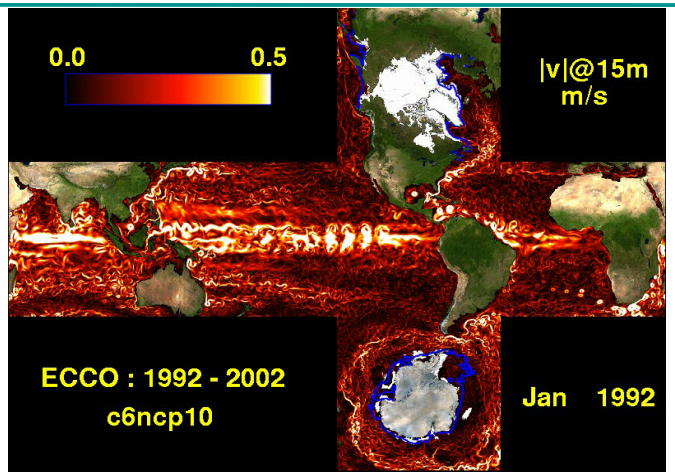
- Sea ice models can be tuned to well reproduce first order velocity fields, even if insufficient sea ice physics are used.
- Common sea ice models are not able to reproduce realistic second order deformation fields [Kwok et al., 2008], which therefore should be used for evaluation.

Tuning a traditional Hibler-type viscous-plastic sea ice model with elliptical yield curve

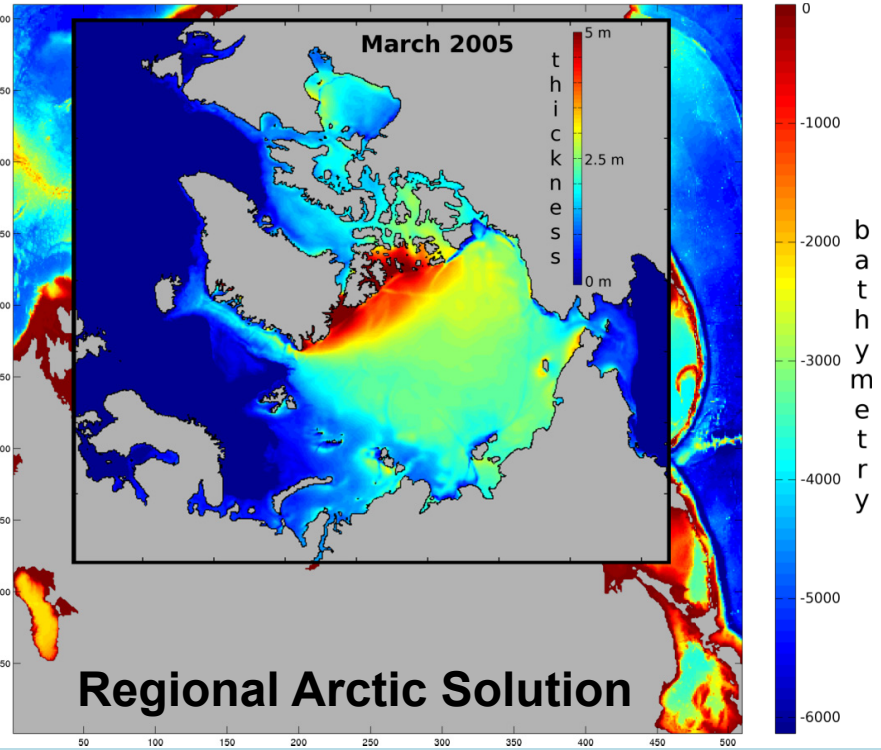
- Sea ice deformation field is not represented correctly in many aspects
- But it is widely used in climate research.

➔ Tune model to best represent observed sea ice kinematics

ECCO2 Coupled Sea Ice-Ocean Model



- ECCO2: High-resolution global ocean and sea ice model constrained by least squares fit to available satellite and in-situ data (Green's function approach).
- Integration period 1992-2008.
- 9 and 18 km grid on cube sphere



Ocean model:

- 50 vertical levels, Volume-conserving, C-grid
- Surface Boundary Conditions: JRA-25
- Initial conditions: WOA05
- Bathymetry: IBCAO

Sea ice model:

- 2-catergory zero-layer thermodynamics [Hibler, 1980]
- Viscous plastic dynamics [Hibler, 1979]
- Initial conditions: Polar Science Center
- Snow simulation: [Zhang et al., 1998]

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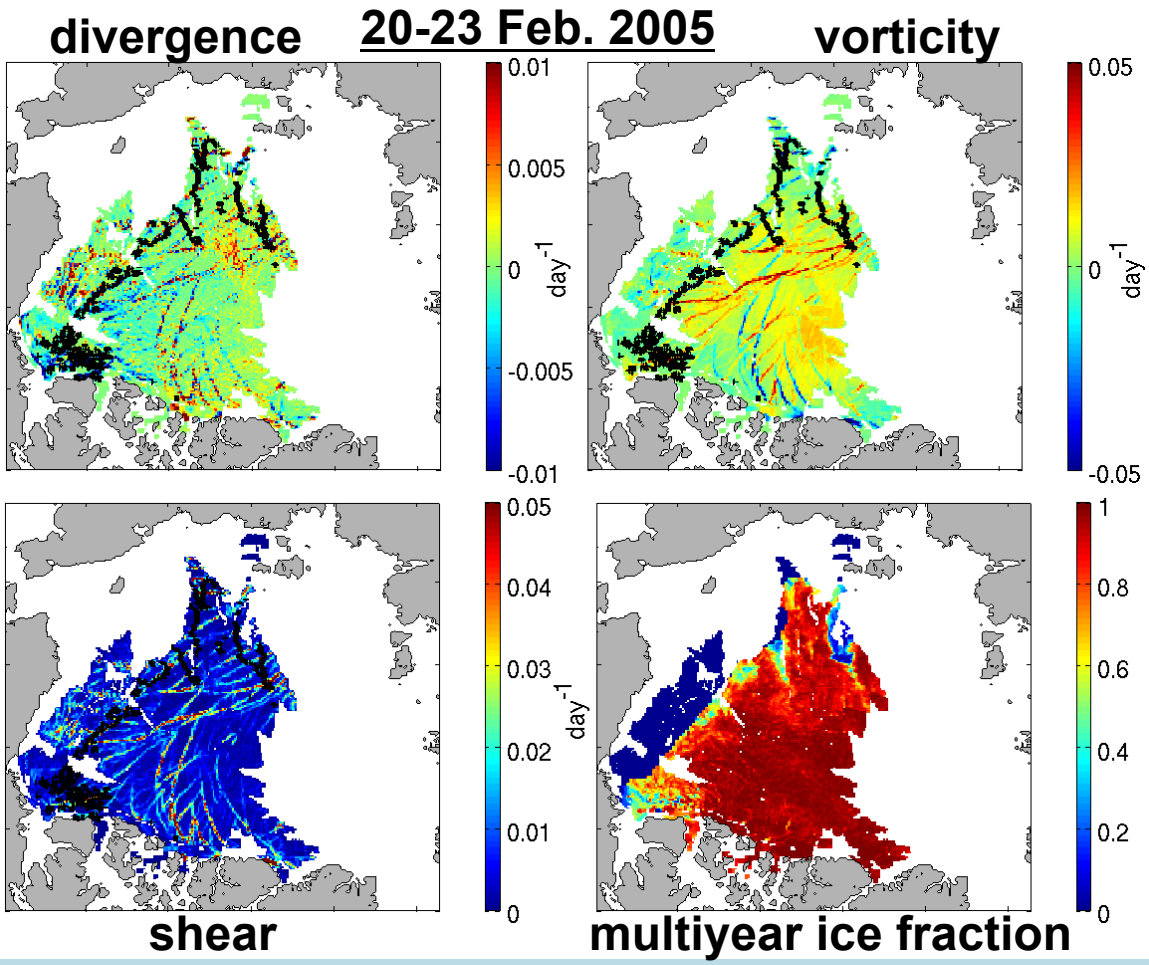
RGPS Satellite Data

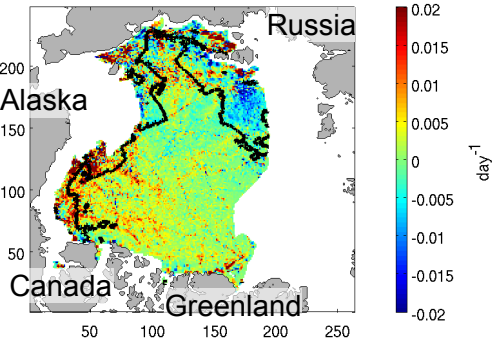
- RADARSAT Synthetic Aperture Radar (SAR) data
- Same region covered approx. every 3 days
- Spatial cross-correlation of patterns ➔ ice movement



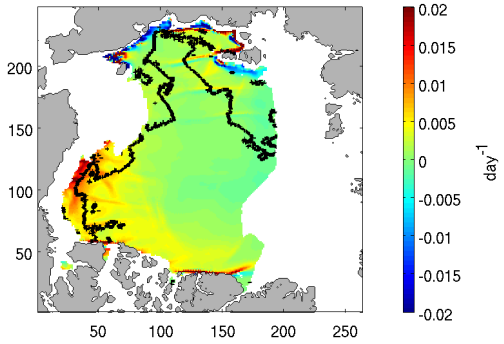
- Initial grid spacing 10 km
- Calculation of deformation (divergence, vorticity, shear) from Lagrangian cells
- 3 daily gridded (12.5 km)
- Accuracy of ice velocities in the order of 100 m (SAR pixel size)
- Discrimination between first- and multiyear ice

RGPS and ECCO2 Sea Ice Deformation

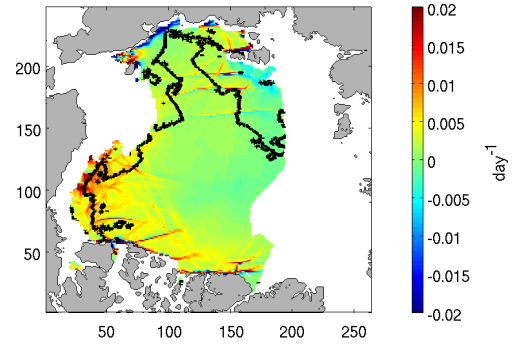
RGPS divergence



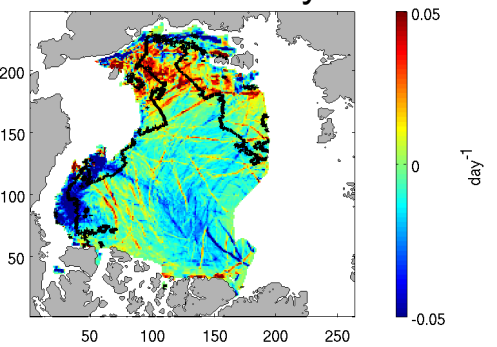
18km divergence



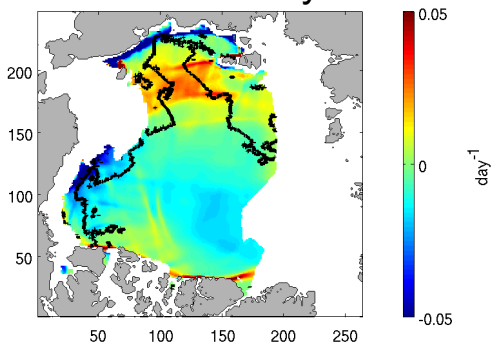
9km divergence



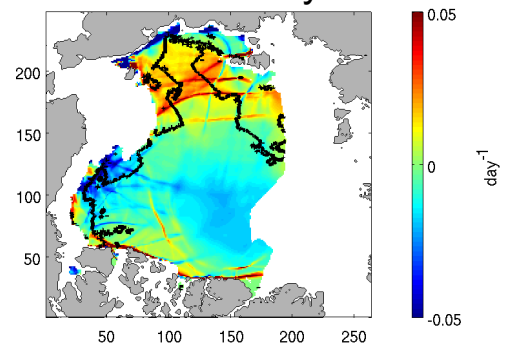
RGPS vorticity



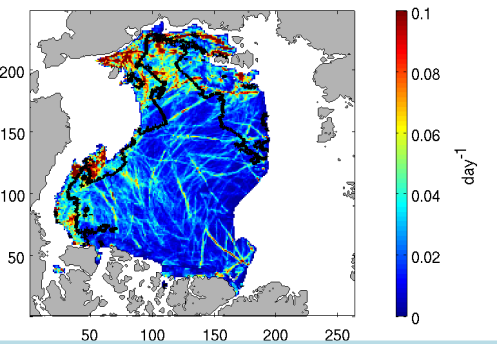
18km vorticity



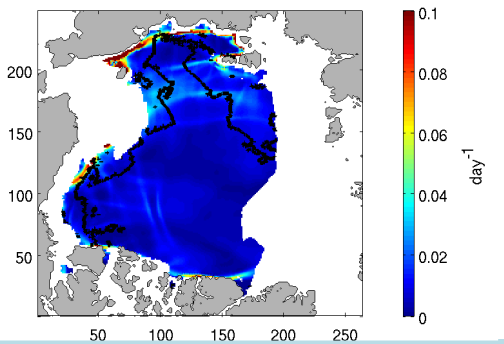
9km vorticity



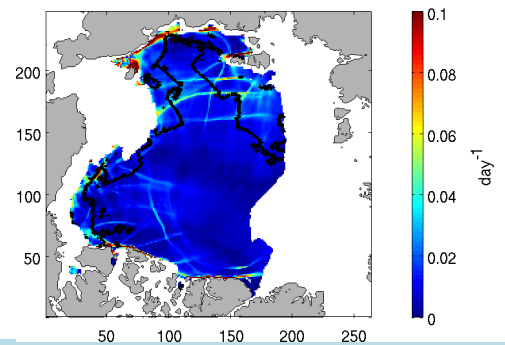
RGPS shear



18km shear



9km shear



November 1997

black line: perennial ice

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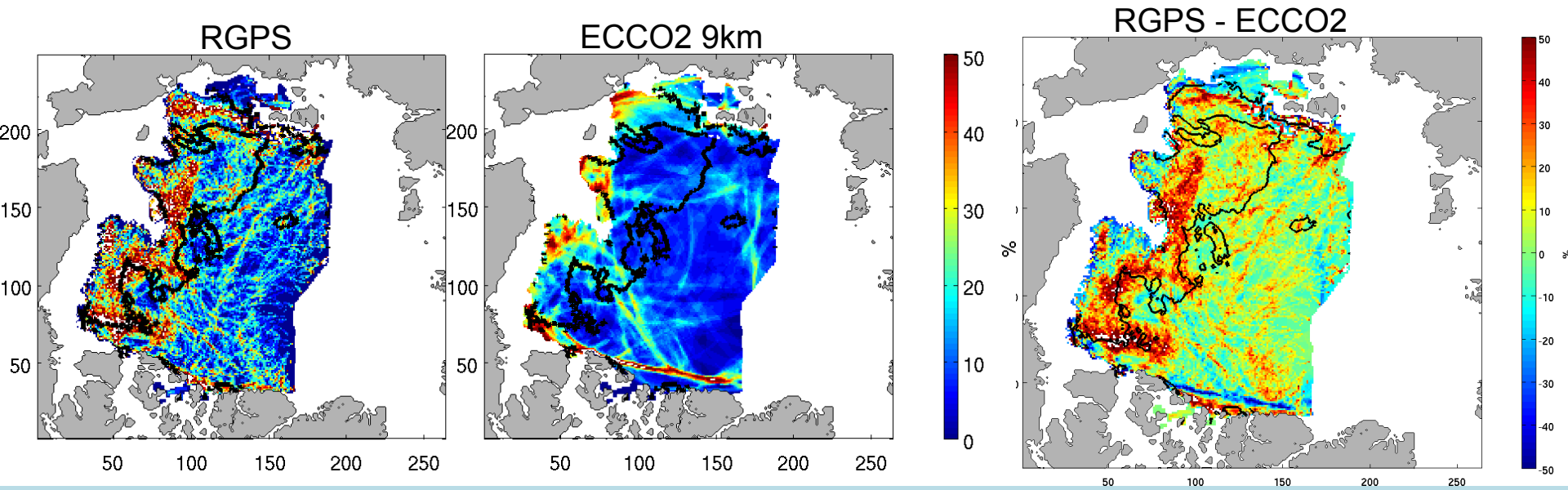
Fractional Number of Deformed Cells

- The absolute amount of deformation variables divergence, vorticity, and shear depends on the spatial scale over which they are measured (e.g. Stern and Lindsay, 2009).
- Using the fractional number of times a grid cell was deformed (div > 0.02/day OR shear > 0.03/day) during a given period for comparisons.

Nov./Dec. 1998



Ice Pressure (Strength)

Sea ice pressure formulation: $P_{max} = P^* h^n e^{[C^*(1-a)]}$

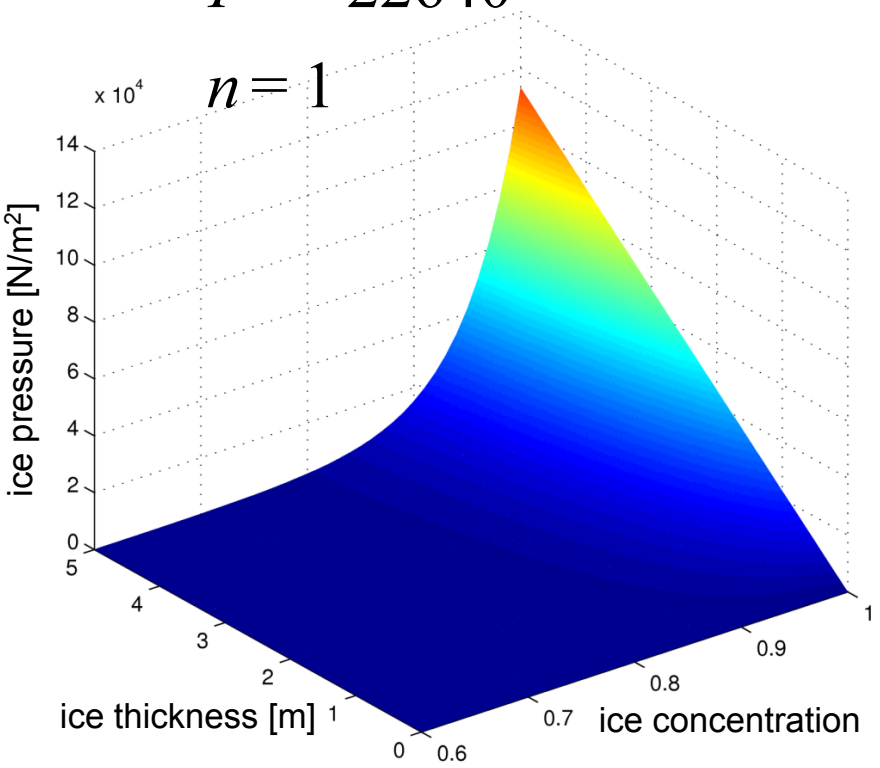
h : ice thickness, $C^* = -20$

a : ice concentration

Control parameterization:

$P^* = 22640$

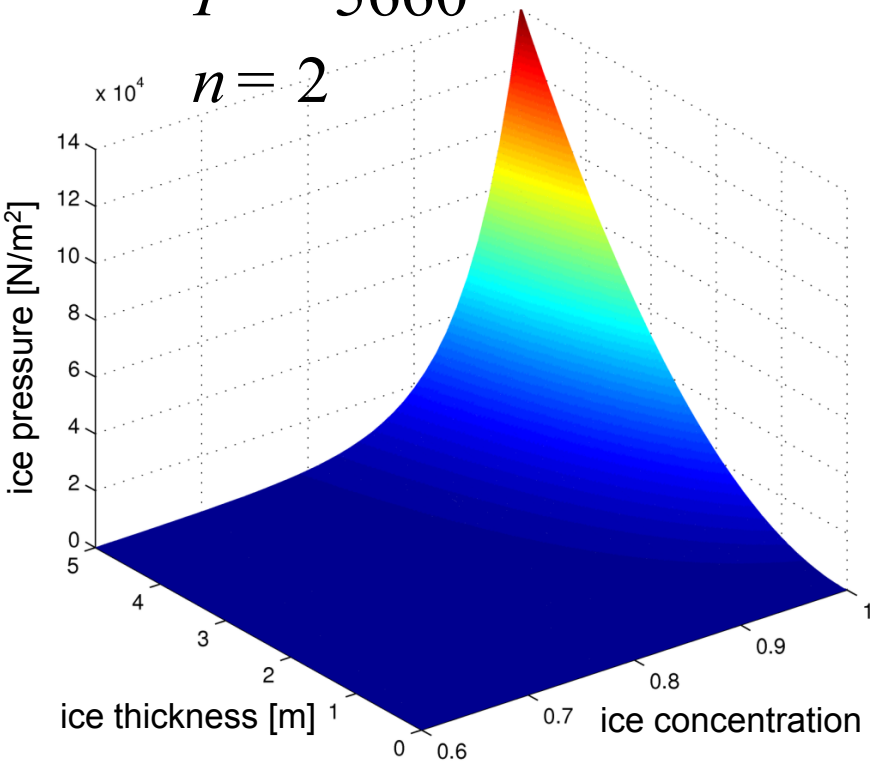
$n = 1$



Test parameterization:

$P^* = 5660$

$n = 2$

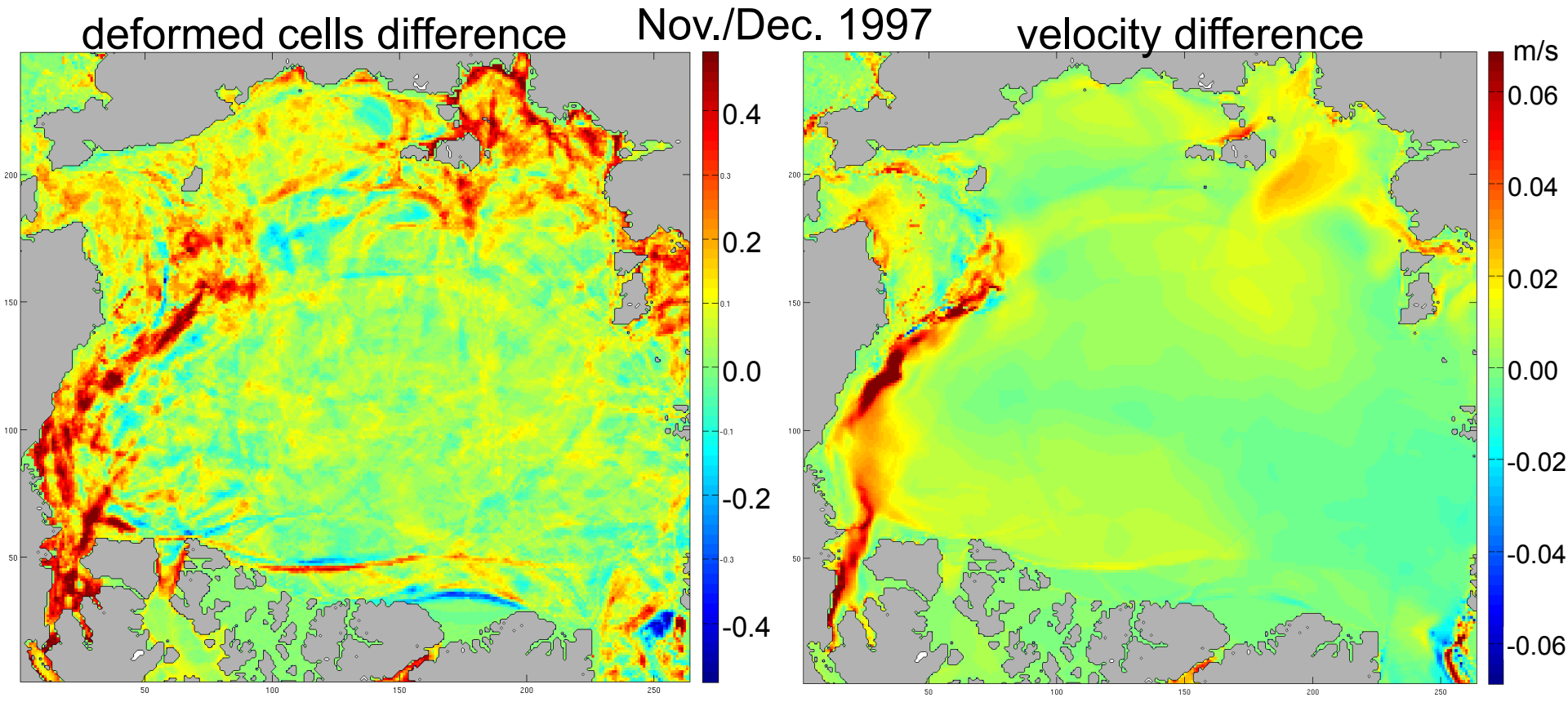


Test – Control Difference

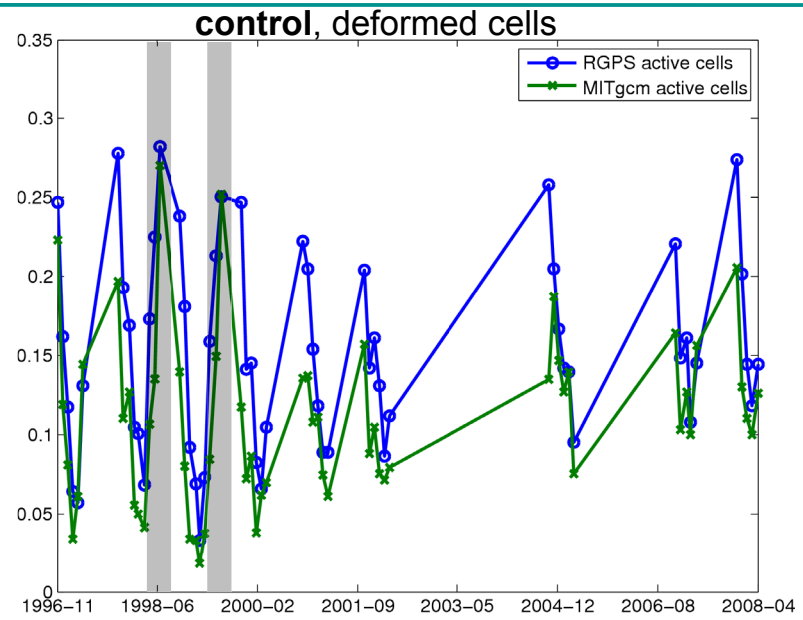
- Difference in fract. number of deformed cells and velocity: Test – Control ice strength formulation

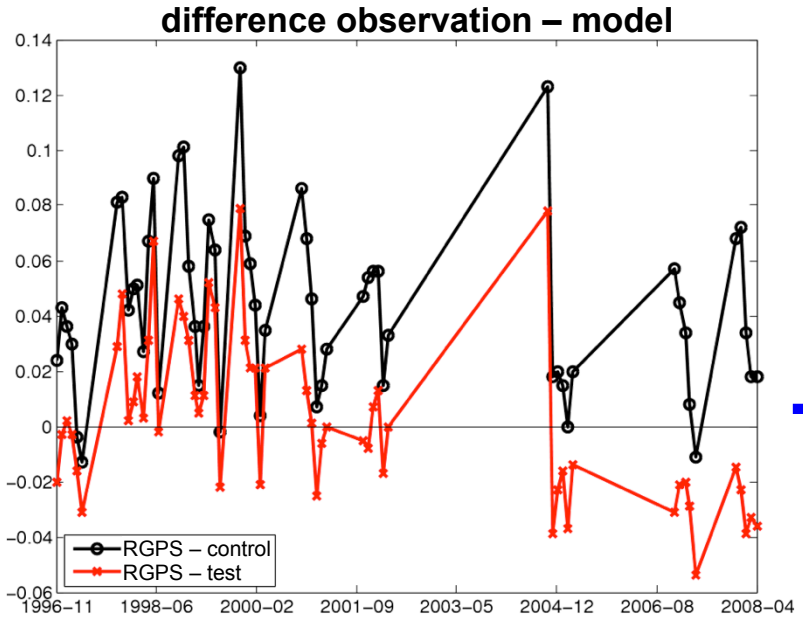
➔ More deformed cells, especially in seasonal ice zone.

➔ Higher ice velocity in seasonal ice zone.



Time Series of Deformed Cells





Time series of deformed cells 1996-2008 (only two summers).

Difference RGPS–ECCO2

	mean [%]			st. dev.	corr.
	all	MY	FY	all	all
18km control	4.3	3.0	7.0	8.4	0.86
18km test	0.3	0.6	1.3	5.7	0.88
9km control	4.2	2.5	7.5	8.3	0.86
9km test	-0.1	-0.4	1.0	5.9	0.90

All: 58 months

MY, FY: 26 months

➔ New ice pressure formulation improves ice deformation distribution independent of model resolution.

Conclusions

- Sea ice deformation fields from observed RGPS data and ECCO2 model results are different, especially for small scale deformations and linear kinematic features (LKF).
- Increase in model resolution produces more and stronger confined ice deformation features. However, the large scale deformation distribution and magnitude does not change significantly.

➔ model physics seem to be inadequate for correct reproduction of some aspects of sea ice kinematics.

- By changing the model sea ice strength formulation away from the linear dependence on ice thickness the modeled and observed deformation fields are getting more consistent.

Thank you!